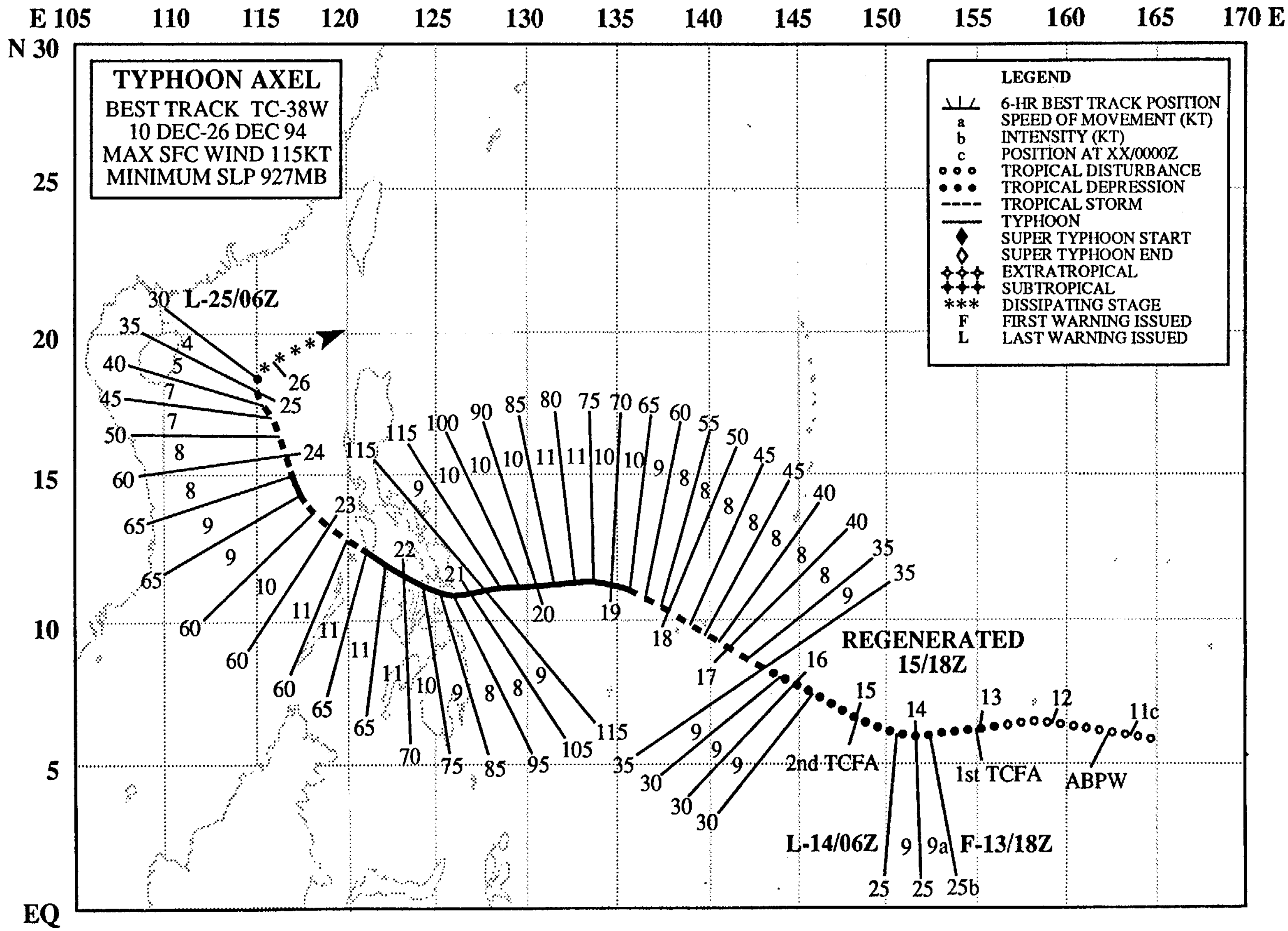

TYPHOON AXEL
BEST TRACK TC-38W
10 DEC-26 DEC 94
MAX SFC WIND 115KT
MINIMUM SLP 927MB
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 105
110
115
120
125
130
135
140
145
150
155
160
165
170 E
N 30
25
20
15
10
5
EQ
L-25/06Z
REGENERATED
15/18Z
2nd TCFA
1st TCFA
ABPW
L-14/06Z
F-13/18Z

TYPHOON AXEL (38W)

I. HIGHLIGHTS

Axel formed in an active near-equatorial trough during the second week of December after a month of no tropical cyclone activity in the western North Pacific basin. At first, the tropical depression that became Axel failed to mature. The JTWC issued its first warning on the system when it was near Chuuk, then issued a final warning 12 hours later. Thirty-six hours after this final warning, regeneration occurred, and the JTWC resumed warning on the system. Axel crossed the central Philippines and caused extensive damage and loss of life. Approximately 24 hours prior to impacting the Philippines, satellite imagery indicated a very rapid, but brief intensification followed by rapid weakening.

II. TRACK AND INTENSITY

After Zelda (37W) dissipated east of Japan in early November, the tropics of the the western North Pacific became very quiet (i.e., the amount of deep convection was greatly reduced), and for more than a month thereafter, no significant tropical cyclones occurred. Axel ended this long period of inactivity as it formed in an active near-equatorial trough (Figure 3-38-1) during the second week of December. For several days prior to Axel's formation, the equitorial region near the international date line was the site of a large cluster of mesoscale convective complexes loosely organized in the twin-trough pattern of Figure 3-38-1a. By 13 December, a distinct low-level circulation center broke away from the cloud cluster and move toward the west. This circulation (pre-Axel) was accompanied by a twin circulation in the Southern Hemisphere (pre-TC 04P) (Figure 3-38-1b).

The tropical disturbance that became Axel was first mentioned on the 110600Z December Significant Tropical Weather Advisory based upon indications from surface reports in the eastern Caroline Islands that a broad surface circulation with an estimated minimum sea-level ppressure of 1006 mb lay beneath an upper-level anticyclone. A Tropical Cyclone Formation Alert was issued at 130100Z based upon 20-30 kt winds measured at an automated weather station on Oroluk Atoll, and also upon improvements in the satellite-observed organization of deep convection in the system. When synoptic observations at Chuuk (WMO 91334) included a gradient-level wind of 35 kt (18 m/sec) and a sea-level pressure below 1004 mb, the first warning was issued on Tropical Depression 38W at 131800Z. Twelve hours later, at 140600Z, a final warning (warning number 3) was issued on Tropical Depression 38W. Quoting from the remarks on this final warning:

"... Tropical Depression 38W has lost its organization, and has weakened over the past 12 hours. The system is ill defined, and has multiple, weak circulations associated with it. ... [it] will be closely monitored for signs of regeneration. ..."

At 142330Z, a second formation alert was issued as the remnants of Tropical Depression 38W began to show signs of regeneration (i.e., an increase in the amount and organization of deep convection near the center of the broad low-level circulation). At 151200Z, warning number 4 was issued on the regenerated Tropical Depression 38W. At 161200Z, the system was upgraged to Tropical Storm Axel. Then, based on satellite imagery that revealed an 11 nm banding eye, Axel was upgraded to typhoon intensity at 190000Z.

Upon reaching 11°N at 181800Z, Axel turned from a west-northwestward heading to a westward heading. The prognostic reasoning for the track forecast at 190000Z included the following comments:

"... our track forecast is still for Axel to lift slightly [i.e., gain latitude] over the next 24-36 hours then track westward under the subtropical ridge. In the latter part of the forecast period, Axel should begin to dip back [i.e., move west-southwestward] over the southern Philippine islands. . . ."

After moving straight westward until 201200Z, Axel dipped slightly in latitude and passed south of the Philippine island of Samar between 210600Z and 211200Z, and then made landfall on the island of Leyte shortly after 211200Z. The estimated peak intensity of 115 kt (59 m/sec) occurred at 201200Z while Axel was east of the Philippines. As Axel neared the Philippine archipelago, the intensity fell to 85 kt (44 m/sec). The intensity dropped below the typhoon threshold after Axel crossed the Philippines and entered the South China Sea. Later, while in the South China Sea west of Luzon, Axel re-intensified to a minimal typhoon for two warning periods (231200Z and 231800Z). Thereafter, Axel weakened, and the final warning was issued at 250600Z when the deep convection and upper-level cloud cover was sheared away to the east of the exposed low-level circulation center. The system dissipated over water about 200 nm (370 km) southeast of Hong Kong.

III. DISCUSSION

a. Genesis in a near equatorial trough

According to climatology (e.g., Sadler et al. 1987), during November and December, the low-level monsoon westerly winds of the western Pacific collapse into a narrow band straddling the equator between 5°N and 5°S. At these latitudes, near-equatorial troughs are found which separate the monsoonal westerlies from the tradewinds to their north and south. Tropical cyclones may develop in the trough of either hemisphere, and sometimes they do so symmetrically, resulting in tropical cyclone twins.

The eastward penetration of monsoonal westerlies can be correlated to the values of the indices of the El Niño/Southern Oscillation (ENSO) (Lander 1994b); it is greatest when the Southern Oscillation Index (SOI) is strongly negative. During some years when the SOI is very low, the equatorial westerlies extend beyond the international date line. During the summer and autumn of 1994, the SOI was very low. By November 1994, equatorial westerlies pushed eastward into the Marshall Islands. Associated with these equatorial monsoonal westerlies was a region of large-scale deep convection resembling the depiction in Figure 3-38-1a.

The disturbance which became Typhoon Axel developed in the near-equatorial trough of the northern hemisphere (Figure 3-38-1b) in a large-scale monsoonal cloud system such as the one shown in Figure 3-38-1a. Typical of many tropical cyclones that form in the latter part of the year at low latitude in the eastern reaches of a near-equatorial trough, Axel intensified very slowly. After Axel moved a significant distance to the west along the trough axis, gained latitude, and broke from the extensive cloudiness associated with the equatorial westerlies it intensified more rapidly (Figure 3-38-1c). Axel was associated with a twin — TC 04P. Twin tropical cyclones develop simultaneously in each hemisphere and are symmetrical with respect to the equator (Lander 1990) (e.g., see Figure 3-38-1b).

b. Very short-lived high-intensity cloud signature

During the 24-hour period spanning 200000Z through 210000Z, Axel's satellite- observed cloud pattern underwent a remarkable evolution from a pattern indicative of a moderately intense typhoon, to a cloud pattern indicative of an extemely intense typhoon, and then back to a cloud pattern indicative of a moderately intense typhoon. The intensity of a tropical cyclone may be estimated from certain characteristics of its satellite cloud signature using techniques developed by Dvorak (1975, 1984). Most of the time, these characteristics evolve gradually, and the estimated intensity of a deepening tropical cyclone

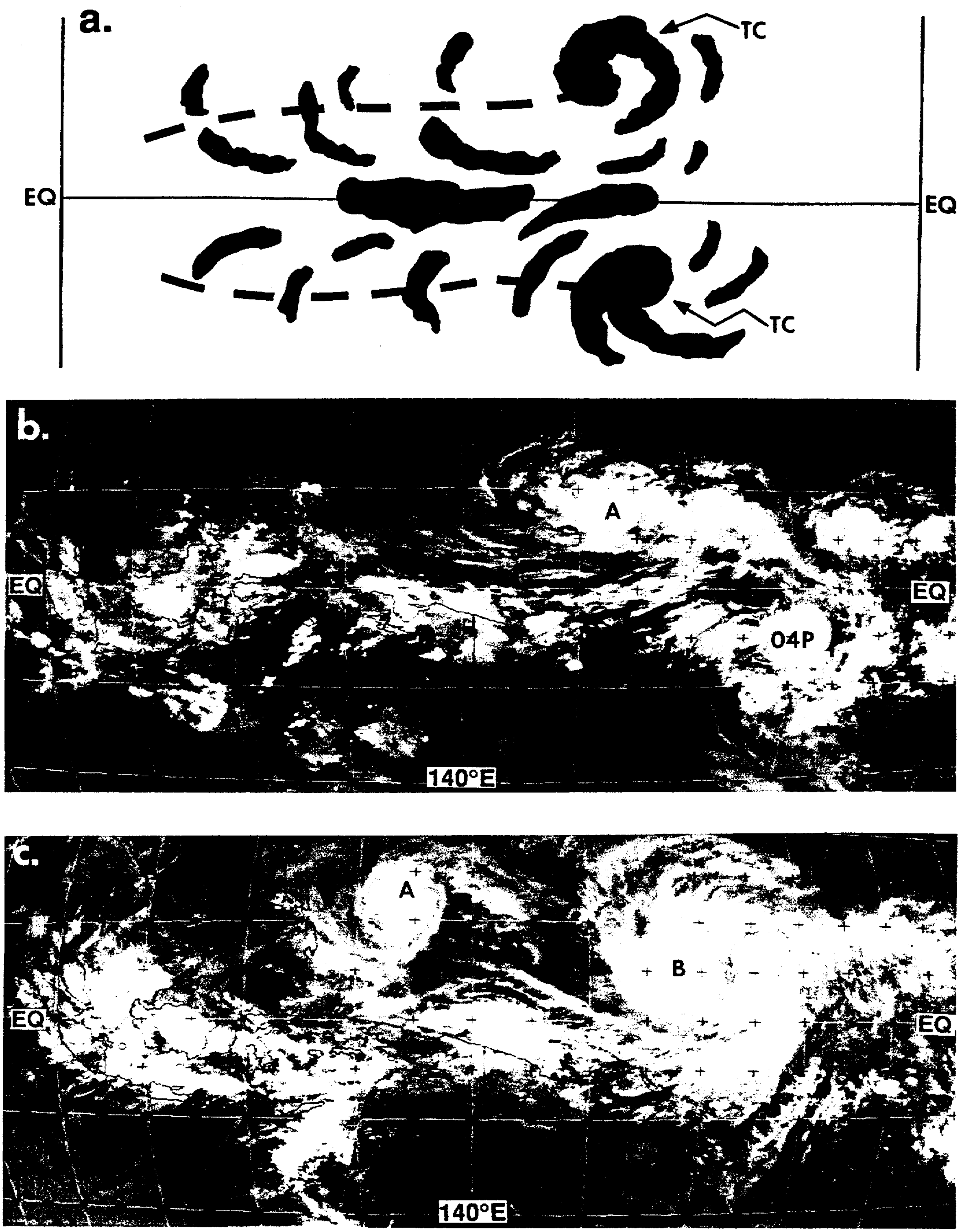
a.
TC
EQ
EQ
TC
b.
A
EQ
EQ
04P
140°E
c.
A
B
EQ
EQ
140°E

Figure 3-38-1 **(Preceeding page)**(a) Schematic illustration of the twin-trough pattern that is common in the western Pacific during November and December. Black silhouettes indicated deep convection. Dashed line shows axes of the near-equatorial troughs. Tropical cyclones (labeled TC) are forming in each hemisphere. (b) Axel (labeled A) and Tropical Cyclone 04P are seen developing in near symmetry within a cloud pattern associated with twin near-equatorial troughs (122131Z December infrared GMS imagery). (c) Axel (labeled A) has moved west-northwestward along the axis of the monsoon trough and has become separated from the monsoonal cloudiness along the equator. A large monsoon depression (labeled B) that bacame Bobbie (39W) is seen forming at the eastern reaches of the monsoon trough in approximately the same area that Axel had formed a week earlier (190031Z December infrared GMS imagery).

typically rises by one "T" number per day until the peak intensity is reached. Few tropical cyclones reach a peak intensity above a T 6.0 (i.e., greater than 115 kt).

At 200532Z, the estimated intensity of Axel, based upon satellite imagery, was 77 kt (40 m/sec) (i.e., a "T" number of 4.5). A dramatic sharpening of Axel's eye, accompanied by thickening and cooling of the tops of the eye wall cloud, took place over the next six hours. An intensity estimate of T 7.0 may be derived from the 201231Z cloud signature (Figure 3-38-2). Zehr (personal communication), who developed an automated Dvorak routine, registered a T 7.3 for Axel at this time. However, soon after this peak, the eye (and the eye wall cloud) became poorly defined: the eye wall cloud tops warmed, and breaks appeared. At 202331, the estimated T number had dropped to 5.0 (see Table 3-38-1). For deepening tropical cyclones, the intensity of the tropical cyclone parallels the T number (i.e., there is no lead or lag between the satellite-observed T number and the corresponding intensity of the tropical cyclone). Axel is a rare case where the satellite intensity estimates exhibited extraordinarily large and extremely rapid changes. Without ground truth or in situ measurements, it is not possible to determine if the changes in the satellite-observed cloud signature of Axel corresponded to similar extraordinarily large and extremely rapid changes in the maximum sustained wind.

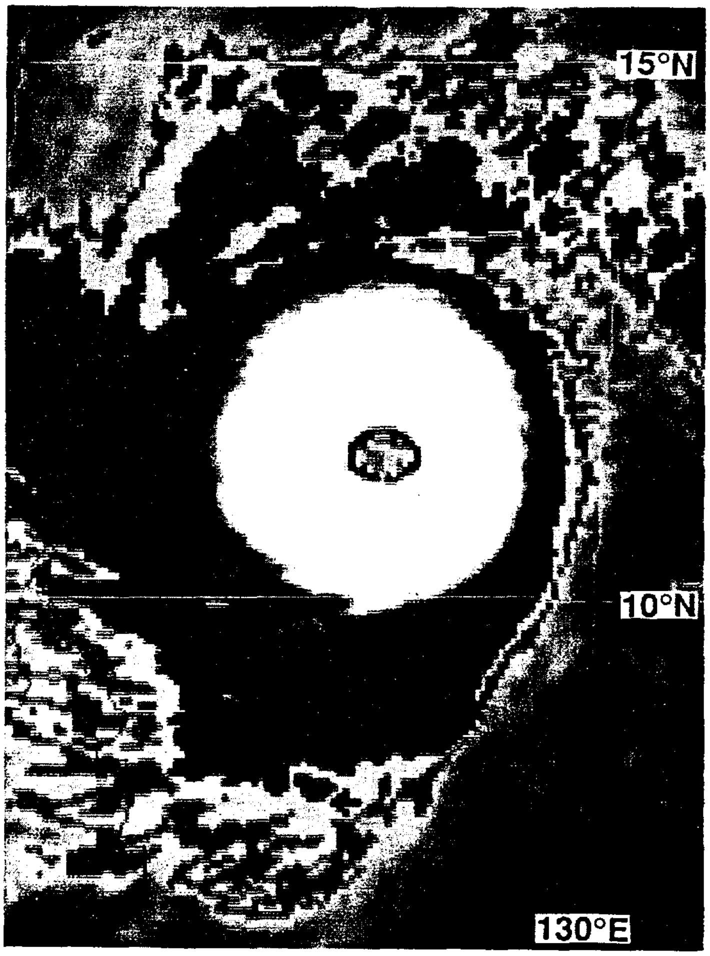

Figure 3-38-2 Axel shown at a time when its satellite cloud signature acquired characteristics of an extremely intense typhoon. The enhancement curve know as MB highlights the well-defined eye and the azimuthally symmetric wide and cold-topped eye wall. (201231Z December infrared GMS imagery).

IV. IMPACT

Axel's greatest impact was to the central Philippines. At 180000Z, with an intensity of 50 kt (26 m/sec), Axel passed 30 nm (55 km) to the north of Yap where only minor damage to vegetation was reported. In the Philippines, however, Axel's impact was far more serious. At least 12 people died in the central Philippines. Flood waters breached a dam, drowning five people and injuring 25 in Bacolod City, 260 nm (480 km) southeast of Manila. In Talcoban City, capital of Leyte province, seven people died and 17 were reported missing. On the southern island of Mindanao, huge waves whipped up by the approaching typhoon destroyed 163 houses, leaving 897 people homeless. In total 1,443 houses were destroyed, leaving at least 7,930 people homeless. A 12-hour power blackout affected Manila when strong winds knocked down a major transmission line on Luzon.

TABLE 3-38-1 Estimated intensity of Axel from Enhanced Infrared Imagery (EIR) during the period 200031Z December to 202331Z December.

Time	T number	Corresponding wind speed
200031Z	4.5	77 kt (40 m/sec)
200532Z	4.5	77 kt (40 m/sec)
200831Z	5.5	102 kt (53 m/sec)
200931Z	5.5	102 kt (53 m/sec)
201024Z	6.0	115 kt (59 m/sec)
201131Z	7.0	140 kt (72 m/sec)
201231Z	7.0	140 kt (72 m/sec)
201331Z	7.0	140 kt (72 m/sec)
201531Z	6.5	127 kt (65 m/sec)
201624Z	6.5	127 kt (65 m/sec)
201831Z	5.5	102 kt (53 m/sec)
202031Z	5.5	102 kt (53 m/sec)
202331Z	5.0	90 kt (46 m/sec)